EVALUATION OF PHYSIOLOGICAL STRESS DUE TO SCHOOLBAG CARRIAGE AMONG CHILDREN IN WEST BENGAL AND SOME SUGGESTIVE REMEDIAL MEASURES: AN ERGONOMIC STUDY

SYNOPSIS OF THESIS

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INTRODUCTION

Schoolbag carriage among children is an intriguing cause of concern since it generates multiple manifestation of stress. The rate of increase of various forms of physiological stress due to this schoolbag carriage is a global concern.

Physiological parameters, posture and perception of pain of the children were affected by heavy schoolbag (Adeyemi et al., 2014). Weight of schoolbag is one of the various ergonomic stressors that contributes to musculoskeletal discomfort among school children. Mandatory heavy load of the schoolbag is considered as an unnoticed daily physical stress which has potential to produce musculoskeletal symptoms (Whittfield et al., 2005). Recent report of Health care Committee of Associated Chambers of Commerce and Industry of India (ASSOCHAM) revealed that majority of children carried heavy schoolbags and they might suffer from mild back pain which could lead to the development of chronic pain. Early degeneration of spine, postural scoliosis, spondylitis, spondylolisthesis, early slip discs and persistent back pain are some of the negative consequences that these children face (ASSOCHAM, 2016). Heavy bag weight, long carriage duration and inaccessibility of lockers probably culminated into the development of musculoskeletal symptoms (Whittfield et al., 2001). Reports of occurrence of lower back pain had significant positive correlation with duration of schoolbag carriage (Mwaka et al., 2014). Backpack weight and duration of carriage influenced changes of shoulder and cervical posture (Chansirinukor et al., 2001).

Primary and secondary school going children undergo growth and development. These children are young but exposed to this mandatory load carriage similar to or heavier than their older counterparts (Dockrell et al., 2006).

Schoolbags that contribute more than 10% of the body weight (BW) were found to be detrimental to the physiological status of the individual (Hong et al., 2000). Trunk flexion angle and Borg (CR 10) rating were significant during walking between 10% and 15% backpack loads of BW while no significant difference was observed between 0% and 10% loads of BW condition (Bauer et al., 2009). Access to school lockers and reduction of weight of schoolbag are major factors which require to be implemented to reduce the backpack carriage related back pain (Skaggs et al., 2006).

In Indian context, there is scarcity of studies regarding socioeconomic status (SES), demography and gender specific quantification of weight of schoolbag and duration of carriage. Extensive

research is also required to find out the correlation between these ergonomic stressors and magnitude of schoolbag carriage related pain among children of different SES.

Study recommended that 10% load of BW caused least disturbances in the metabolic process. Significant difference was observed in energy expenditure, oxygen uptake and recovery blood pressure when the load increased from 10% to 20% load of BW (Hong et al., 2000).

A comparative evaluation of weight, duration of schoolbag carriage among children belonging to different SES is necessary for recommending remedial measures in order to bring about effective improvement of health, safety, growth, development and well-being of the children.

Heavy weight of schoolbag, prolonged duration of carriage and improper method of carriage are resulting into various forms of physiological stress. Thus, it is important to measure weight of schoolbag and duration of carriage while load was carried in both shoulders by children of different SES, habitat and gender. Assessment of various forms of physiological stress due to schoolbag carriage in children of different SES is essential to recommend status specific remedial measures. Association of weight of schoolbag, duration of carriage with occurrences of perceived pain is required to be investigated among children of different cross sections. This evaluation is important to find out combined effect of weight of schoolbag and duration of carriage on occurrences of pain and suggest remedial measures.

Evaluation of adverse effects of schoolbag carriage among children is not new but a comparative study of various forms of physiological stress among children based on their SES is a virgin area to delve into.

REVIEW OF LITERATURE

Daily carriage of backpacks was a frequent contributor of discomfort in children (Negrini et al., 2002). Researchers found that the heavy bag weight, long carriage duration and inaccessibility of lockers might culminate into the production of musculoskeletal symptoms (Whittfield et al., 2001).

Study was conducted to find out the relationship between pain and schoolbag carriage in students aged between 11-14 years (n=176). It was found that shoulder and other bodily pains that were experienced by sample of scholars were strongly related to bag type and their gender (Puckree et al., 2004).

Self-reported backpack related pain was found to be significantly associated with perception of weight of backpack and duration of carriage. Assumed posture and gender were also observed to be associated significantly with reported symptoms. SES and habitat of the children might contribute to reported pain related to backpack (Talbott et al., 2009).

Magnitude of pressure acting on both shoulders due to carriage of heavy backpack by children (n=10, age 12-14 years) was investigated. The researchers found pressure when loaded at 10%, 20%, and 30% of BW on both shoulders during high back or low-back conditions; the pressure yielded was higher than the threshold (approximately 30 mm Hg) to cause occlusion of skin blood flow. Backpack carriage related shoulder and back pain might be due to asymmetric distribution of high pressure exerted for prolonged duration (Macias et al., 2008).

An investigation into the weight of schoolbag and prevalence of musculoskeletal symptoms among students in third and sixth- form (n=14) with mean age between 13.6-17.1 years showed that schoolbag weight as percentage of BW ranged from 13.2% and 10.3% of their BW respectively. Students might exceed the recommended guidelines for load carriage limit for industrial adult workers. Prevalence of symptoms were most in neck, shoulder, upper and lower back (Whittfield et al., 2005).

School children (n=22) were diagnosed with the help of pressure mark (redness or swelling) at neck and shoulder which corresponded to the backpack straps. It was also observed that children assumed stooping posture during backpack carriage, accompanied by pain in the neck, upper back and shoulders. Similar symptoms were absent during school holidays (Sharan et al., 2012).

On analysing the mean schoolbag weight of secondary school going students (n=57, mean age 13.1 years), it was seen that the mean weight of schoolbag was 6.2 kg and the mean percentage of BW carried in form of schoolbag was 12% of the BW. In such cases, the level of discomfort was reported to be very high. Maximum discomfort was felt in the shoulder region, followed by the back region (Dockrell et al., 2006).

In Indian context, prevalence of backache and other health issues related to back was reported among 68% of urban school-going children between the ages of 7 to 13 years. (ASSOCHAM, 2016).

During childhood, excessive weight could lead to spinal misalignment, further affecting musculoskeletal maturity offensively. Children who carried weight of more than 10% of their

BW showed poorer lung function (The children schoolbag, limitation on weight bill, Rajya Sabha, Bill No. LXXXVI.2006).

Middle school children belonging to age group 11 -14 years (n=20) were made to stand and walk on treadmill with 0%, 5%, 10%, 15 %, 20% loads of BW. Electromyography, evaluation of posture, measurement of heart rate and perception of exertion were noted. The volunteers were made to stand and walk. The study tried to recommend a load limit based on the significant changes brought about on the individual by the measured parameters. No significant changes were seen in trunk flexion angle and Borg scale rating (CR10) between carriage of 0% to 10% load of BW but significant changes developed while carrying between 10% and 15 % load of BW. Hence, it was inferred it is preferable to carry load not exceeding 10 % of BW (Bauer et al., 2009).

Primary school children of 10 years of age (n=15) walked on treadmill at 1.1 m/s speed with no load and load of 10%, 15% and 20% of BW for a duration of 20 minutes. During walking, ventilation significantly increased and breathing frequency became rapid with 15% and 20% loads of BW. No significant change was brought in posture of trunk and parameters associated with respiration while carrying 10% load of BW (Li et al., 2003).

High school students (n=15,male) of 12.5±0.5 years age were made to carry backpacks with 8%, 10.5% and 13% of their BWs on a treadmill (1.1 m/s , duration- 15 min) and compared with no load condition. Systolic blood pressure (SBP) and diastolic blood pressure (DBP), heart rate, minute ventilation (MV) and respiratory frequency were recorded 3 times: during rest, post exercise and after recovery (3 minutes). During carriage and 3 minutes after carriage, SBP and MV were significantly higher when assigned with loads of 10.5 and 13% of BW than in case of no load and load of 8% of BW whereas, DBP significantly increased at 13% of BW load (Daneshmandi et al., 2008)

Recommended load limit for backpack weight carriage for boys of 10 years is 10% of their BW. Recovery time for blood pressure was significantly prolonged and trunk forward lean was increased at backpack carriage of 15% of BW (Hong et al., 2000).

Schoolbag weight was found be different among rural and urban children. One study showed heavier bags were carried by rural children compared to that of their urban counterparts (Siddalingappa et al., 2015). But another study revealed schoolbag weight among urban children was significantly heavier compared to that of rural children (Mwaka et al., 2014).

Internationally and nationally there is paucity of studies to evaluate various forms of physiological stress due to schoolbag carriage among male and female children of different SES and habitat. There are evidences of some studies in laboratory condition but studies conducted in realistic field condition are essential to ensure the future generation with better health condition.

AIM AND OBJECTIVES

1. To collect baseline data about the weight of the schoolbag, method and duration of carriage among the children of different groups.
2. To comparatively evaluate the physiological stress among the children due to schoolbag carriage and recommend remedial measures.
3. To investigate the association between the weight of the schoolbag, its position, duration of carriage and the occurrence of musculoskeletal disorder, pain in different parts of the body among children exposed to daily schoolbag carriage and to assess the discomfort level.

MATERIAL AND METHODS

Cross sectional study was conducted among urban and rural male and female school children of 8-15 years of age in different districts of West Bengal, India. Initially, standardized questionnaire (Aggarwal et al., 2005) was used to evaluate the SES of the children. These children were distributed into different categories based on their SES. Finally 400 (n) children, 50 (n) in each group were randomly considered for the study. The children were selected by cluster sampling method, multistage random stratified sampling was done following standard statistical guidelines.

Children with any sort of congenital defects or pathological conditions were not considered for the study. Consent letters were filled up by the parents and participants before the collection of data. All data were collected following 'Institutional Ethical Committee (Human)' and Declaration of Helsinki guidelines.

Assessment of socio-economic status:

A detailed scale for assessment of SES of the family was employed (Agarwal et al., 2005). Children were distinctly grouped according to their socio-economic score. Scores greater than or equal to 46 indicated high SES whereas scores less than 46 indicated low SES in this study as per standard guidelines (Salvendy, 2012).

Measurement of anthropometric parameters:

Anthropometric measurements were done by standardized technique (Lohman et al., 1988). Height was measured using Martins Anthropometric rod (Seiber & Heigner, Switzerland) nearest up to 1 mm. Weight was measured using weighing machine (Libra, India) nearest up to 0.5 Kg.

Derived indices of children were computed with standardized formulae: body mass index (BMI) (Key et al., 1972), waist to hip ratio (WHR).

Determination of weight of schoolbag: The bag was directly put on the weighing scale and again the bag weight was computed from the difference between the BW of the children in loaded condition and unloaded condition. The bag weight carried by the children was then expressed as percentage of BW.

Body composition analysis:

Body fat percentage, lean percentage, body fat mass index, fat free mass index were assessed among children based on bioelectrical-impedance analysis using BODYSTAT 1500 MDD (Houtkooper et al., 1992).

Assessment of duration of carriage:

Duration of carriage was noted by direct interview of the children (Dockrell et al., 2016) and it was further verified by the distance they commute from their home to school and the mode of transport they avail. This information was again crosschecked either with the class teachers of the concerned pupil or their parents. Distance between their residence and school was also noted. Their walking speed was also recorded to validate the data obtained from the questionnaire.

Assessment of perceived pain:

All the children participating in the study were asked to self-report the occurrence and magnitude of pain due to carriage of their schoolbag. They were shown a body part chart from

which they identified the regions of body where pain occurred. They also bolstered their pain perception by rating the magnitude of pain on a subjective scale (0-10) (Corlett et al., 1976 and Wilson et al., 1985).

Assessment of perception of schoolbag load:

Perception of schoolbag load was noted as the children expressed the feeling of carrying the load. The load that the children carried was measured. Based on the actual load, those less than or equal to 10 % of BW was considered to be 'light', greater than 10% of BW to less than or equal to 15 % of BW as 'heavy' and greater than 15 % of BW as 'very heavy'. The children were asked to rate the heaviness of load according to the same verbal anchors, to assess their perception of load.

Assessment of cardio-respiratory response:

Children without any complain of illness and with regular use of schoolbags were asked to perform an experimental protocol. Each child was randomly made to carry load of 8% of BW, 12 % of BW and 16% of BW as carried on both shoulders in posterior mode. Equal distribution of weight was maintained for schoolbags. Each child walked briskly (this being their preferred pace of walking during daily commute with schoolbag) for an approximate distance of half mile in three courses with adequate rest interval between the courses (minimum 15 minutes) with each magnitude of load (Joseph et al., 2014). The temperature ranged between 27^0 C to 30^0 C. Attempt to measure blood pressure before and after the test was made. Heart rate, oxygen uptake and energy expenditure were assessed using polar heart rate monitor and K4b2.

Assessment of postural stress:

Children were pictographed and video graphic recordings were done while they performed the experiment designed with different magnitude of schoolbag load carriage as well as while they commuted to school naturally, carrying their bags. Stick diagrams were prepared from frozen frame video recording. Analysis of the schoolbag carriage method and frequently assumed postures during carriage was done using ovako working posture assessment system (OWAS) and rapid entire body assessment (REBA) with the help of software ergofellow 2.0. Score 1, 2 and 3 are assigned for load exposures of less than or equal to 10 kg, greater than 10Kg to less than or equal to 20 kg, greater than 20kg respectively in OWAS. In REBA score 0, 1 and 2 were assigned for load of less than11lbs, 11lbs to 22lbs and greater than 22lbs respectively. In case of schoolbag carriage in children, same scores were designated for load carriage of less than or equal to 10%, greater than 10% to less than or equal to 15% and greater than 15% of BW

respectively for OWAS and REBA. While carrying 20% load of BW, ground reaction forces (GRF) differed significantly. Backpack load carriage of 20% of BW caused increase in vertical GRF almost three times compared to carriage of 10% of BW (Shasmin et al., 2006).

Statistical analysis:

Mean, ±standard deviation and percentage were calculated for different parameters of children of different groups using MS Excel 2007. Two tailed Student's t test was performed to find out the significant difference between the parameters of different groups. This was followed by one tailed t test to assess which one was significantly higher. In both the cases, significance was considered at 0.05 level ($p<0.05$). Multiple correlation using MS Excel 2007 was performed to find out the association between weight carried as percentage of BW and duration of carriage with reported pain in shoulder, neck and back (Das et al., 2012).

RESULTS AND DISCUSSION

Schoolbag weight has been expressed both as absolute weight and percentage of BW. The measure in terms of percentage of BW rather than absolute weight is more preferred since BW varies with differences in age, gender and SES. SES is a major determinant of nutritional status. Nutritional status is manifested by the BW of an individual and can be further corroborated by several computed indices of nutritional anthropometric parameters. Majority of the children (both male and female) of different SES and habitat carried schoolbag load exceeding the recommended limit of 10% load of BW. Duration of carriage among the children belonging to low SES irrespective of habitat and gender was prolonged than their high SES counterpart.

In this study emphasis was given on comparative assessment of absolute weight of schoolbag and weight carried by children as percentage of their BW among urban and rural children based on their SES and gender. The mean absolute weight of schoolbag carried by children of same habitat and gender of high SES was significantly higher compared to that of their low SES counterpart ($p<0.05$) expect between rural female children of high and low SES. But, no significant difference was observed in mean weight carried as percentage of BW ($p>0.05$) except between rural female children of high and low SES (significantly higher in the first group, $p<0.05$). As, mean BW of the children of low SES (expect rural females) was significantly lower compared to their counterpart belonging to higher SES ($p<0.05$), schoolbag load carriage as percentage of the BW between the groups became insignificant ($p>0.05$). Mean schoolbag weight carried as percentage of BW was significantly higher among rural female children of

high SES compared to that of children belonging to low SES ($p<0.05$). Interestingly, mean weight of these female children of low SES was significantly higher compared to that of their high SES counterpart ($p<0.05$).

There was no significant difference between mean age of different socio-economic groups of children regardless of their habitat and gender. Mean of weight and BMI were significantly lower in case of children from low SES compared to those of high SES irrespective of habitat and gender. But, rural female children of high SES showed a different trend in this regard.

Among urban children of high SES, mean of body fat percentage was higher than the mean of normal range. In case of urban children of low SES, mean of body fat percentage was lower than the mean of normal range. Among rural male children of high SES, mean of body fat percentage was higher than the mean of normal range. Rural female children high SES and low SES and rural male children of low SES however had a mean body fat percentage lower than the mean of normal range

Children were not able to report pain in definite segments of the back i.e., upper, mid and lower. They were asked to report occurrence and magnitude of pain in 'back' region. All the children could report the magnitude of pain in neck, shoulder and back region.
Occurrences of self-reported pain were identified to be predominant in shoulder, neck and back among children. Variation in reported pain was found to exist with SES of the children. In majority cases, percentage of children reported pain was higher in SES compared to that of high SES irrespective of gender and habitat.

This study showed the perception of schoolbag load at different weight of actual schoolbag carriage as percentage of BW. Distinct difference was observed between the actual schoolbag load carriage according to the hypothesis and perception of those loads by the children.

Manifestation of cardiopulmonary stress was assessed when children were assigned with different loads of less than 10% of their BW, 10-15% of their BW and greater than 15% of their BW. Augmentation of heart rate, oxygen consumption and energy expenditure were observed in the children belonging to high SES compared to those of their lower SES counterparts (except for mean heart rate in female children when assigned with 12% load of BW and mean oxygen consumption in males when assigned with 8% load of BW) although the increase was not of statistical significance. Thus, it may be inferred that both male and female children are susceptible to cardiopulmonary stress irrespective of their SES when subjected to schoolbag load

carriage. No significant difference was observed in environmental temperature during schoolbag carriage among children (male and female) of high and low SES. Walking speed of the children ranged from 4.4 km/h to 4.8 km/h. Measurement of blood pressure after the assigned load carriage could not be performed due to lack of practical feasibility.

There is scarcity of studies on children performing realistic schoolbag load carriage in field condition. A study was carried out in laboratory condition where fifteen primary school children aged 10 years walked with no load, 10%, 15% and 20% of their BW on treadmill for duration of 20 minutes. Mean heart rate (bpm), oxygen consumption (ml/min) and energy expenditure (Kcal/min) during schoolbag carriage of 8% of BW in field condition were higher in male children of high SES compared to means of those parameters of primary school children of Hong Kong at 15% load of BW at 20 minutes with a speed of 1.1m/sec (Hong et al., 2000). Similar result was observed for mean heart rate and oxygen consumption in male children of low SES when compared to mean of those parameters of primary school children of Hong Kong at same condition. In case of male and female children of both SES, mean heart rate during schoolbag carriage of 8% of BW was more than that of preadolescent agricultural workers (age group 10-13 years, both male and female) of West Bengal, India during crop carriage on head mode (Gangopadhyay et al., 2005). In case of female children of high and low SES, mean heart rate during schoolbag carriage of 8% of BW was more than that of teenage girls (age group 14-17 years) during brick carriage on head mode in brick manufacturing units in West Bengal, India (Sahu et al., 2010).

In case of OWAS, postures of back, arm, leg and amount of load expressed as absolute weight were assessed to find out the risk of postures adopted during schoolbag carriage. In case of REBA, postures of neck, trunk, leg, upper arm, lower arm and wrist were evaluated by using REBA. Score 1, 2 and 3 were assigned for load exposures of less than or equal to 10 kg, greater than 10Kg to less than or equal to 20 kg, greater than 20kg respectively for analysis of postural risk by OWAS method. Score 0, 1 and 2 were assigned for load of less than 11lbs i.e., less than 5Kg, 11lbs to 22lbs i.e., 5 Kg to 10Kg and greater than 22lbs i.e., greater than 10 Kg respectively for postural risk assessment using REBA.

In this extensive study conducted, it was found that schoolbag weight for children rarely exceeded 10Kg. However, according to OWAS, carriage of absolute weight of up to 10 Kg load generated a score of ‘1’. In case of children, high variation in BW indicated the same load as 22.8% to 36.4% of their BW which is much beyond the acceptable load limit and has been

inferred to increase susceptibility towards musculoskeletal symptoms. The multifactorial computation of OWAS score generated an action category of '2' which is probably not the accurate reflection of the propounded postural stress. This probable discrepancy is due to not considering the assigned score for load as percentage of BW.

In case of postural stress analysis using REBA revealed that score '2' was assigned up to 10 Kg of load. In case of children, high variation in BW indicated the same load as 22.8% to 36.4% of their BW which is much beyond the acceptable load limit and has been inferred to increase susceptibility towards musculoskeletal symptoms. As per exact REBA analysis for most frequent postures, total score was 3 i.e., 'low risk, change may be needed' which is probably not the accurate reflection of the experienced postural stress. The limitation of posture assessment tools to evaluate the schoolbag carriage related postural stress among children embarks the necessity of their modification when applied.

When the schoolbag load was less than or equal to 10% of BW, most of the postures were identified to be hazardous and 'corrective actions required in the near future' (action category 2). But, during schoolbag load carriage of greater than 10% to less than or equal to 15% of BW and greater than 15% of BW, frequently assumed postures were hazardous and 'corrective actions should be done as soon as possible' (action category 3). OWAS was used to evaluate working posture of preadolescent agricultural male and female workers of age group of 10-13 years (Gangopadhyay et al., 2005). As per exact REBA analysis, postures were at low risk, change might be needed. But when postures were evaluated as per modified scores, it was observed that most of the postures were at low to medium risk, indicating change might be required to further investigation and changes were required soon.

This study found that combined effect of weight and duration of schoolbag carriage culminated to occurrences of shoulder pain among urban male children of low SES ($p<0.05$), urban female children of high SES ($p< 0.05$), rural male children of low SES ($p <0.05$), rural female children of low SES ($p<0.05$); neck pain among urban male children of low SES ($p<0.05$), urban female children of high SES ($p<0.05$), rural male children of low SES ($p <0.05$), rural female children of low SES ($p<0.05$); back pain among urban male children of low SES ($p<0.05$), urban female children of low SES ($p<0.05$), rural male children of low SES ($p <0.05$), rural female children of low SES ($p<0.05$)

CONCLUSION

This study revealed the necessity of SES and nutritional status specific load limit optimization among school children. It also necessitates the reconsideration of acceptable load limit and the implementation of methods to mitigate schoolbag carriage related physiological stress.

Schoolbag carriage related various forms of physiological stress are an alarming concern. The novel perspective of the study lies in the quantification of stress among children which is going to reveal a new genre of interpretations of interaction of SES with cardiopulmonary stress and perception of pain among male and female children. Ergonomic intervention based on physiological stress assessment will contribute to the reduction of physiological cost during routine work of schoolbag load carriage. The scourge of various forms of physiological stress can probably be vanquished; better health condition among children may be assured in an attempt endowed with the symbiotic interaction of ergonomic and nutritional intervention. This study will provide evidence which could be used by the authorities to frame their policies focusing on the specific area of 'healthy back education' and nutritional improvement for children through a school-based health promotion initiative.

RECOMMENDATIONS

The observations and evaluations have intrigued the development of certain guidelines, which on implementation will ameliorate the stress generated by daily mandatory schoolbag load carriage performed by children. Physiological cost of schoolbag carriage was more than that of children involved in crop and brick carrying activity in agriculture and brick manufacturing sector respectively even during carriage of 8% load of their BW. Thus the load should be below 10% of BW. Further studies are required to find out the acceptable load limit based on nutritional and SES.

Depending on the physiological cost during schoolbag carriage, maximum acceptable load limit should be determined and subsequently ergonomic attempt be made to design the schoolbag based on this weight. Special attention must be given by schools on bag weight carried by the children based on parameters like distance traversed by the child, children with exceptionally low BW, children complaining of pain or injury

Symbiotic interaction of all the recommendations and its rigorous implementation will definitely help to eliminate primordial possibilities of chronic ailments among the future citizens of the nation. Awareness programs involving children, parents and school authorities must be regularly

conducted so that the potential stressors may be avoided in daily practices of schoolbag load carriage. This aims at the replacement of ephemeral smile with a permanent one on the little faces, where just going to school and returning from there is not stress but joy.

BIBLIOGRAPHY

- Adeyemi AJ, Rohani JM & Rani MA. Back pain arising from schoolbag usage among primary school children. International Journal of Industrial Ergonomics. 2014; 44(4):590-600.
- Aggarwal OP, Bhasin SK, Sharma AK, ChhabraP, Aggarwal K & Rajoura OP. A New Instrument (Scale) for Measuring the Socioeconomic Status of a Family: Preliminary Study. Indian Journal of Community Medicine. 2005; 30 (4): 111-114.
- ASSOCHAM, 2016. http://assocham.org/upload/news/1473082317.pdf.
- Bauer DH & Freivalds A. Backpack load limit recommendation for middle school students based on physiological and psychophysical measurements. Work. 2009; 32(3):339-350.
- Chansirinukor W, Wilson D, Grimmer K & Dansie B. Effects of backpacks on students: measurement of cervical and shoulder posture. Australian Journal of Physiotherapy. 2001; 47(2):110-116.
- Corlett EN & Bishop RP. A technique for assessing postural discomfort. Ergonomics. 1976; 19(2):175-182.
- Daneshmandi H, Rahmani-Nia F & Hosseini SH. Effect of carrying school backpacks on cardio-respiratory changes in adolescent students. Sport Sciences for Health.2008; 4(1-2):7-14.
- Das D & Das A. Statistics in Biology and Psychology. 6th ed. Academic publishers, India, 2012.
- Dockrell S, Kane C & O'keefe E. Schoolbag weight and the effects of schoolbag carriage on secondary school students. Ergonomics. 2006; 9(1):216-222.

- Dockrell S, Blake C & Simms C. Guidelines for schoolbag carriage: An appraisal of safe load limits for schoolbag weight and duration of carriage. Work. 2016; 53(3):679-688.

- Gangopadhyay S, Das B, Das T & Ghoshal G. An Ergonomic Study on Posture-Related Discomfort Among Preadolescent Agricultural Workers of West Bengal, India. International Journal of Occupational Safety and Ergonomics. 2005; 11(3):315-322.

- Hong Y & Brueggemann GP. Changes in gait patterns in 10-year-old boys with increasing loads when walking on a treadmill. Gait & Posture. 2000; 11(3):254-259.

- Hong Y, Li JX, Wong AS & Robinson PD. Effects of load carriage on heart rate, blood pressure and energy expenditure in children. Ergonomics. 2000; 43(6):717-727.

- Houtkooper LB, Going SB, Lohman TG, Roche AF & Van Loan MA. Bioelectrical impedance estimation of fat-free body mass in children and youth: a cross-validation study. Journal of Applied Physiology. 1992; 72(1):366-373.

- Joseph S & Sengupta A. Effect of Backpack Carriage Position on Physiological Cost and Subjective Responses of University Students. Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, Kraków, Poland Edited by Ahram T, Karwowski W and Marek T. 19-23 July 2014; 5899-5906.

- Key A, Fidanza F, Karvonen MJ, Kimura N & Taylor HL. Indices of relative weight and obesity. Journal of Chronic Diseases. 1972; 25 (6): 329-343.

- Li JX, Hong Y & Robinson PD. The effect of load carriage on movement kinematics and respiratory parameters in children during walking. European Journal of Applied Physiology. 2003; 90(1-2):35-43.

- Lohman TG, Roche AF & Martorell R. Anthropometric Standardization Reference Manual. Human Kinetics Books, Chicago. 1988.

- Macias BR, Murthy G, Chambers H & Hargens AR. Asymmetric loads and pain associated with backpack carriage by children. Pediatric Orthopaedics Journal. 2008; 28 (5):512 -517.

- Mwaka ES, Munabi IG, Buwembo W, Kukkiriza J & Ochieng J. Musculoskeletal pain and schoolbag use: a cross-sectional study among Ugandan pupils. BMC Research Notes. 2014; 7(1):222.

- Negrini S & Carabalona R. Backpacks on! School children's perceptions of load, associations with back pain and factors determining the load. Spine (Phila Pa 1976). 2002; 27(2):187-195.

- Puckree T, Silal SP & Lin J. Schoolbag carriage and pain in school children. Disability and Rehabilitation. 2004; 26 (1): 54-59.

- Sahu S, Sett M & Gangopadhyay S. An ergonomic study on teenage girls working in the manual brick manufacturing units in the unorganized sectors in West Bengal, India. Journal of Human Ergology. 2010; 39(1):35-44.

- Salvendy G. Handbook of Human Factors and Ergonomics. 4th ed. Wiley publishers, USA, 2012.

- Sharan D, Ajeesh PS, Jose JA, Debnath S & Manjula M. Back pack injuries in Indian school children: risk factors and clinical presentations. Work. 2012; 41(Supplement 1):929-932.

- Shasmin HN, Abu Osman NA, Razali R, Usman J & Wan Abas WA. A preliminary study of acceptable load carriage for primary school children. 3rd Kuala Lumpur International Conference on Biomedical Engineering. Springer Berlin Heidelberg. 2006 2007; 171-174.

- Siddalingappa H, Murthy N, Kulkarni P, Shrinivasa BM, Sunilkumar D & Renuka M. Burden of Heavy Schoolbag among High School Students and Its Relation with Their Physical Growth in Mysore and Chamarajanagar District. International Journal of Health Sciences and Research. 2015; 5(9): 8-14.

- Skaggs DL, Early SD, D'ambra P, Tolo VT & Kay RM. Back pain and backpacks in school children. Journal of Pediatric Orthopaedics. 2006; 26(3):358-363.

- Talbott NR, Bhattacharya A, Davis KG, Shukla R & Levin L. School backpacks: it's more than just a weight problem. Work. 2009; 34(4):481-494.

- THE CHILDREN SCHOOLBAGS (LIMITATION ON WEIGHT) BILL, 2006. AS INTRODUCED IN THE RAJYA SABHA ON THE 8TH DECEMBER, 2006, Bill No. LXXXVI. 2006. MGIPMRND—4149RS (S5)—8-12-2006.

- Whittfield JK, Legg SJ & Hedderley DI. The weight and use of schoolbags in New Zealand secondary schools. Ergonomics. 2001; 44(9):819-824.

- Whittfield JK, Legg SJ & Hedderley DI. Schoolbag weight and musculoskeletal symptoms in New Zealand secondary schools. Applied Ergonomics. 2005; 36(2): 193-198.

- Wilson JR & Corlett EN. Evaluation of human work- a practical Ergonomic methodology. Taylor and Francis, London. 1985.